METHOD OF PREPARING FOLDABLE HYDROPHILIC OPHTHALMIC DEVICE MATERIALS

FIELD OF THE INVENTION

This invention relates to photopolymerizable acrylic ophthalmic device materials. In particular, this invention relates to the use of benzoylphosphine oxide initiators in blue-light curing of foldable hydrophilic ophthalmic device materials.

BACKGROUND OF THE INVENTION

The two most common types of polymerization initiators for ophthalmic device materials are thermal initiators and photoinitiators. Typical thermal initiators, including free radical initiators such as peroxides, initiate polymerization as temperature is increased. In some cases, two or three temperature tiers are involved such that curing involves a schedule of temperature/time combinations. Thermal initiation generally requires holding the monomer composition at elevated temperatures for lengthy periods of time. Total cure times of twenty-four hours are not unusual. See, for example, U.S. Pat. No. 5,290,892.

Photoinitiators generally offer the advantage of relatively short cure times and, unlike thermal initiators, can be used at ambient conditions, eliminating the need for high-temperature equipment or special ovens. Photoinitiators are activated by light of one or more specified wavelengths, rather than heat. Photoinitiation of ophthalmic lens materials is known. See, for example, U.S. Pat. No. 5,290,892.

The most common types of photoinitiators known or used for curing ophthalmic lens polymers are probably ultraviolet UV-sensitive photoinitiators. UV-sensitive photoinitiators are, however, generally not suitable for use with lens materials that contain a UV-absorbing chromophore. UV-absorbing chromophores present in an ophthalmic lens composition can interfere with the ability of UV-sensitive photoinitiators to efficiently cure the composition. Today, UV-absorbing chromophores are frequently incorporated in ophthalmic lens materials in order to reduce or block UV light from reaching the retina. Although methods are known for temporarily "blocking" UV absorbing chromophores during processing, thereby preventing interference with a UV-initiator, these methods require that the UV-absorber be "un-blocked" after the composition is cured. The UV chromophore can be "un-blocked" by either chemical or thermal means. "Un-blocking" is generally complicated and can add 4–6 hours to processing times, offsetting some or all of the time advantages offered by photoinitiators.

In addition to UV-sensitive photoinitiators, visible-light initiators are also known. For example, U.S. Pat. No. 5,224,957 discloses photopolymerizable compositions useful in forming an intraocular lens in situ. The compositions are delivered into the natural lens capsule or a thin plastic shell substitute and then polymerized. The reference compositions contain 90–99.99% by weight of at least one polyfunctional acrylic and/or methacrylic acid ester. Suitable acid esters include bisphenol A or bishydroxypolyalkoxy bisphenol A derivatives lengthened with ethylene oxide or propylene oxide.

The compositions of the '957 patent are cured using photoinitiators which absorb light in the range 400–500 nm. Suitable initiators include alpha-diketones, in particular camphorquinone, benzil and phenanthrene quinone, and mono and bisacylphosphine oxides. According to the '957 patent, particularly preferred initiators are "for example 2,4,6-trimethylbenzoyldiphenylophosphine oxide and bis-(2,6-dichlorobenzoyl)-4-n-propylphenylphosphine oxide or bis-(2,6-dichlorobenzoyl)-4-n-butylphenylphosphine oxide" (see Col. 3, lines 12–16).

International Patent Application Publication No. WO 96/28762 also discloses photocurable compositions comprising acrylic components. The compositions contain specified amounts of di(meth)acrylates, poly(meth)acrylates, urethane(meth)acrylates, and oligomeric di(meth)acrylates based on bisphenol A or bisphenol F. The photoinitiator may be "any photoinitiator which forms free radicals when irradiated suitably." Suitable classes include benzoin ethers; acetophenones; benzil; anthraquinones; benzoylphosphine oxides (e.g., 2,4,6-trimethylbenzoyldiphenylphosphine oxide); benzophenones. Photoinitiators particularly suitable for use with argon ion lasers include 2,4,6-trimethylbenzoyldiphenylphosphine oxide.

SUMMARY OF THE INVENTION

The present invention relates to methods for preparing foldable hydrophilic ophthalmic device materials that contain a benzoylphosphine oxide photoinitiator and a hydrophilic device-forming materials selected from the group consisting of 2-hydroxyethylmethacrylate; 2-hydroxyethylacrylate; N-vinylpyrrolidone; glyceryl methacrylate; glyceryl acrylate; polyethylene oxide mono- and dimethacrylates; and polyethylene oxide mono- and diacrylates. The methods comprise activating the benzoylphosphine oxide photoinitiator with a blue-light source.

Among other factors, the present invention is based on the finding that such ophthalmic device materials are effectively cured using a blue light source and the benzoylphosphine oxide initiator, 2,4,6-trimethylbenzoyldiphenylophosphine oxide. In contrast, when camphorquinone, which has a greater absorbency in the blue-light region than 2,4,6-trimethylbenzoyldiphenylophosphine oxide, is used in place of the benzoylphosphine oxide initiator, the same ophthalmic device materials are not efficiently cured.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows a sample UV-visible spectrum of the benzoylphosphine oxide initiator 2-4-6-trimethylbenzoyldiphenylophosphine oxide in a 2-phenylethyl acrylate solvent.

FIG. **2** shows a sample UV-visible spectrum of the alpha-diketone initiator camphorquinone in a 2-phenylethyl acrylate solvent.

DETAILED DESCRIPTION OF THE INVENTION AND PREFERRED EMBODIMENTS

According to the present invention, foldable, hydrophilic ophthalmic device materials comprising one or more hydrophilic monomers selected from the group consisting of 2-hydroxyethylmethacrylate; 2-hydroxyethylacrylate; N-vinylpyrrolidone; glyceryl methacrylate; glyceryl acrylate; polyethylene oxide mono- and dimethacrylates; and polyethylene oxide mono- and diacrylates; are prepared using a blue-light source and a benzoyl-phosphine oxide initiator. First, an ophthalmic device material mixture comprising one or more of the hydrophilic a monomers listed above and a benzoylphosphine oxide initiator is prepared. After the mixture is prepared, it is exposed to a blue-light source for a time sufficient to cure the device material.

The hydrophilic monomers specified above are known and are commercially available or can be synthesized using